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SUSTAINABILITY ISSUES IN THE ROAD MAP FOR FINNISH COMPANIES TO THE INDIAN ALGAL BIOFUEL MARKET

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Kestävän kehityksen näkökohtia
suomalaisille yrityksille Intian
leväpolttoainemarkkinoille

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Hupenevat öljyvarat sekä energiahintojen jatkuva nousu ovat saaneet monet maat kiinnostumaan vaihtoehtoisista energianlähteistä. Erityisesti valtiot, jotka ovat riippuvaisia tuontiöljystä, panostavat kotimaisten biopolttoaineiden tuotannon kehittämiseen. Intiassa on suuri tarve biopolttoaineille ja Intian hallitus tukeekin tulevaisuuden biopolttoaineiden tutkimus- ja kehittämistyötä, sillä ne nähdään potentiaalisena ratkaisuna maan kasvavalle energiantarpeelle. Mikrolevät ovat lupaava uusiutuva energianlähde, joiden öljyntuotto hehtaarilla on moninkertainen verrattuna esimerkiksi Intiassa biodieselin lähteenä käytettyyn jatrophaan.

Vuoden 2012 tammikuussa alkaneen ALGIND (Algae Energy Business Opportunities in India for Finnish Companies) -projektin tarkoituksena on etsiä liiketoimintamahdollisuuksia suomalaisille yrityksille leväenergia-alalta Intiassa. ALGIND:ssa on mukana muun muassa Valtion teknillinen tutkimuslaitos ja Lahden ammattikorkeakoulu. Yksi projektin tavoitteista on luoda kokonaisvaltainen kuva leväenergia-alan nykytilasta ja tulevaisuudesta Intiassa. Tässä apuna käytetään roadmap-työkalua, johon on kuvattu alaan vaikuttavia asioita tekniikan, talouden ja kestävän kehityksen näkökulmista. Opinnäytetyö on osa roadmapia ja siinä tarkastellaan asioita, jotka edistävät tai haastavat leväenergian kestävä kehitystä Intiassa. Tulokset perustuvat syksyllä 2013 Intiassa tehtyyn haastattelututkimukseen sekä kirjalliseen tutkimukseen.

Levä on uusiutuva energianlähde, jonka tuotanto voidaan yhdistää sekä jätevedenpuhdistukseen että hiilioksidin talteenottoon. Leväntuotannossa ei tarvita viljelyskelpoista maata tai puhdasta vettä, jolloin levänkasvatus ei kilpaile ruuantuotannon kanssa. Intian olosuhteet ovat pääosin suotuisat levänkasvatukselle, mutta alan kehittymistä kaupalliselle tasolle jarruttaa tällä hetkellä leväöljyn kallis hinta verrattuna raakaöljyyn, jolloin avainasemassa on teknologian kehittäminen tutkimustyön myötä. Jotta ala voisi todella kukoistaa tulevaisuudessa, selkeät lait ja säädökset, jotka tukevat kestävän kehityksen periaatteita, ovat tarpeen.

Asiasanat: mikrolevä, leväbiodiesel, kestävä kehitys, Intia

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ABSTRACT

Depleting oil reservoirs along with escalating energy prices have sparked interest in renewable energy sources globally. Especially countries that are dependent on imported oil are investing in indigenous biofuels. India has a huge market for biofuels, but the industry is still in infancy. The government of India sees biofuels as a potential solution for the increasing energy demand of the country and due to that India promotes the research and development of future biofuels. Microalgae have a better oil yield per hectare than jatropha that is commonly used for biodiesel production in India, which makes microalgae a very promising energy source.

In the beginning of the year 2012 a project called Algae Energy Business Opportunities in India for Finnish Companies (ALGIND) was launched to form the best possible big picture for enhanced algal businesses in India and to create business opportunities for Finnish companies in the Indian algal biofuel market. The project involves Finnish and Indian participants, including VTT Technical Research Centre of Finland and Lahti University of Applied Sciences. One goal of the project is to create a roadmap to illustrate the current state and the future trends of algal energy field from technological, economic and sustainable development points of view. The Bachelor's thesis is part of the roadmap, focusing on the sustainability of algal energy in India.

India's tropical climate favors cultivation and even in conditions not suitable for food production. Since the food security of the country is not very stable, microalgae cultivation can offer a bioenergy source that would not threaten it. Algae cultivation can also be integrated with wastewater treatment and CO₂ capturing. There is no algal oil production in commercial level yet, since it cannot compete with the price of crude oil. Technology needs developing and strict laws and policies have to be created to regulate the field in order to achieve blooming and sustainable energy industry out of microalgae.

Key words: microalgae, algal biodiesel, sustainable development, India, roadmap

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1 INTRODUCTION

The world is facing an energy crisis with depleting oil reservoirs. It is also globally recognized that fossil fuels are impacting the Earth and the climate harmfully, endangering the utilization of natural resources for the future generations. Energy prices are escalating and the trend is very much likely to continue in the future. This has made many nations take actions towards more sustainable and indigenous energy sources, such as biofuels.

Researchers have now taken an interest in future biofuels, and for example algae are seen as a promising energy source. Algae cultivation has got many advantages compared to oil-seed crop cultivation on land, such as better oil yield per hectare, growth speed and a possibility to have a year round crop of algae (Chanakya, Mahapatra, Ravi, Chauhan & Abitha 2012.) Algal oil production can also offer a wide range of high value co-products, such as nutrients, pharmaceuticals and health related products, cosmetics and chemicals. Utilization of high value products as sideproducts in algal oil production could improve the viability of algal biofuels. (Oilgae 2014.)

In the beginning of the year 2012 a project called Algae Energy Business Opportunities in India for Finnish companies (ALGIND), main funder Tekes Groove programme, was launched to form the best possible big picture for enhanced algal businesses in India. The project involves Finnish and Indian participants, including University of Helsinki, VTT Technical Research Centre of Finland, Lahti University of Applied Sciences and Aalto University. The focus of the project is on the development of business aspects in the area of algal biofuels, but since the technology plays a very important role achieving success in this field, ALGIND is closely related to the project ALDIGA (Algae from Waste for Combined Biodiesel and Biogas Production, 2010 – 2012), which focused on mass production of algae in Finnish conditions and the results of the project are available through the ALGIND collaboration.

One objective of the project ALGIND is to create a road map for the use of algae in biofuels and energy production. Road map is a visual tool to be used in long-range planning by companies, organizations, projects etc. A good roadmap gives

the general view of the subject at a glance. It emphasizes the key issues, shows the strengths and weaknesses, and the information is put on a certain timeline. In this road map the aim was to characterize drivers and barriers that affect the algae energy business in India. These drivers and barriers were divided into three areas: economic, technological and sustainability aspects. Part of the content of this thesis project was included in the road map and was published by VTT Technical Research Centre of Finland in VTT Technology 158 (Eemeli Hytönen, Ari Jussila & Sari Kuusikunnas: "Algal energy roadmap in India", available at <http://www.vtt.fi/inf/pdf/technology/2014/T158.pdf>). The thesis is focusing on the sustainability of the algal energy in India, including environmental and socio-ethical drivers and barriers. The aim was to find out the factors that would enable or hinder the sustainable development of the algae energy field in India.

The drivers and barriers in the sustainability issues of the algal energy field in this thesis are formed based on the results of the interview study that took place in the autumn 2013. The study consisted of 15 interviews with Indian experts in the field representing research institutes, universities, companies and organizations. The closer examination of the drivers and barriers is based on literature as well as on the interview study.

2 INDIAN BIOFUEL MARKET AND SUSTAINABILITY ISSUES

The Indian biofuel market has been constantly growing and developing for the past few years. India imports most of the petroleum it uses (about 80%), and during the years 2005 – 2006 the country imported about 99 million tonnes of crude oil. India's diesel consumption is about five times larger than gasoline and it has increased a lot during the last two decades. India is aware of its growing demand of energy due to its rapidly growing economy and increasing population. In order to achieve and maintain energy security, the country is willing to move on towards indigenous renewable energy sources, and especially the shortage of petrodiesel and high price of crude oil drive the need for alternative diesel fuel. (Khan, Rashmi, Hussain, Prasad & Banerjee 2009.)

Renewable energy sources offer a more sustainable option for energy production than fossil fuels. Sustainable development could be defined as a development that meets the needs of the present without compromising the ability of future generations to meet their needs (United Nations 1987.) In the context of algal biofuels, this would imply such production methods that would not endanger the natural resources (land and water), and are also ethical in order to respect the lives of local people. In the Indian context one of the key issues of sustainable development is food security.

In this thesis and in the roadmap for ALGIND the environmental and socio-ethical factors that affect the sustainable development of algal biofuels or lack of it are examined on the basis of an interview study and literature study. There are many environmental drivers that speak for algal energy, but the scarcity of land and water has to be taken into account. India's tropical climate favors the cultivation of algae, and since the food security of the country is not very stable, it would offer a bioenergy source that would not threaten it. India's rural development is facing a crisis, which is harmful for the development of the country, since about half of the population still earns their livelihood out of the agricultural sector. Microalgae cultivation could enhance the rural development and provide more income for farmers and landless rural people.

In the absence of sufficient policies the algal biofuel industry cannot really bloom, even though the Government of India promotes the development of the biofuel sector. Proper policies are also needed to ensure that the algal energy field will develop sustainably.

3 RESEARCH METHODS

3.1 Literature review

The aim of the roadmap that was created for the ALGIND project, which the thesis is part of, was to create a realistic and best possible big picture of the algal biofuel market in India for Finnish companies. In the beginning it was important to get familiar with the ALGIND project and the subject: what is algal energy in general and microalgal biodiesel in particular, what is the current status of the field in India, and what will the future of the algal biofuel look like? This happened through a literature review: the Science Direct database of Elsevier was found to be especially useful, as well as the references that were offered by the VTT. During the background research I also got familiar with ALDIGA and the theses that were made within the project, since they contain a lot of information about mass production of algae. The information gained helped to form a general overview of the algal biofuel field in India, and it also prepared for the forthcoming interview trip.

3.2 Interview study and a trip to India

An important part of the data acquisition was the interview research that took place in India in late October 2013. VTT and Finpro India organized the trip on the whole, and they also found the organizations and people that we were interviewed and scheduled the interviews, although there were a few last minute changes during the trip. Before the interviews I had a couple of meetings and a few phone consultations with Ari Jussila, who is a research scientist in VTT and he also supervised this thesis in order to prepare ourselves for the trip. We discussed the practicalities, the desired content of the interviews, the information that we wanted to achieve and how to approach the interview research in order to get valid data.

The trip lasted eleven days, including traveling days and one day off. Fifteen different appointments with experts in the algal biofuel field took place in four different cities: New Delhi, Pune, Mumbai and Chennai. We had a chance to

interview different kinds of players in the algal biofuel industry representing research institutes, universities, companies and organizations.

After the trip and the interviews we broke down the results of the interview study with Ari Jussila. We went through every interview meeting one by one comparing our notes and had a general discussion about how it went and what impressions we had. The notes were transcribed and they were also accessible to everyone who works with the roadmap.

3.3 Road map

Part of the ALGIND project is to create a roadmap for the use of algae in biofuels and energy production. The road map is an efficient visual tool that is used for long-range planning by organizations, companies, projects etc. Generally, a road map contains specific information and it visualizes the critical assets, relationships between these, skills and technologies that are required to meet the certain goal within a timeframe. It emphasizes the key issues, strengths and weaknesses that have to be taken into account. However, there are various types of road maps, depending on how specific and deep level information is needed and what the purpose of the roadmap is. A good roadmap gives the general view of the subject at a glance.

In this case the objective was to create a roadmap for algae-based business opportunities in India. A key task was to identify the most important economic, technological, environmental and socio-economic trends influencing the current and future prospects of the field. These trends are described as drivers and barriers that either enable or hinder the development of algae energy business in India in the present (1 – 3 years) and in the mid-term (3 – 5 years) or long-term (up to 10 years) future. This thesis focuses on environmental and socio-ethical factors, i.e. sustainable development concerning the algal biofuels.

4 RESULTS

Microalgae have got many drivers, both environmental and socio-ethical that favour the sustainability of energy production from microalgae. However, there are a few issues that may hinder it and they have to be taken into consideration in order to develop a viable algal energy field.

Climate change and increasing carbon dioxide emissions lead to the demand for alternative energy sources. Microalgae cultivation offers an effective tool for reducing the CO₂ emission levels because of its significant capacity to convert CO₂ into biomass. A major driver for microalgae cultivation when compared with oil-seed crops is that microalgae cultivation does not compete with food production, since algae can be cultivated on non-arable land and they do not need fresh water to grow. However, land and water are very sensible resources in India, and that has to be taken into account in order to cultivate microalgae in a sustainable manner. Microalgae cultivation can be utilized in bioremediation, since it can be integrated with wastewater treatment and algae are able to absorb heavy metal from water.

Even though the economy of India is growing rapidly, the development of the agricultural sector is facing a crisis. This is a problem, since agriculture is still a source of livelihood for the majority of rural people. Microalgae cultivation could bring more income to the rural people and create new jobs.

The Government of India supports the research and development of advanced biofuel technologies, such as microalgae. It also promotes the biofuel sector, for example by making biofuel blending mandatory. Currently, India relies on sugar cane and its processing byproducts (molasses) for bioethanol production and jatropha on biodiesel production. Both have problems meeting the biofuel demand. Current bioethanol technologies cannot produce bioethanol at a competitive price, and it has been speculated that if sugar is additionally diverted to the biofuel industry, the food industry would be less able to meet its demand. Jatropha has not been able to meet the biodiesel demand either, due to several issues, for example lack of sufficient jatropha seeds, as well as lack of high-

yielding drought-tolerant cultivars. It is obvious that more sufficient energy sources are needed and algae could provide a sustainable solution.

However, in order to develop an effective and sustainable biofuel field from microalgae, the Government of India should take actions towards creating extensive policies to regulate the field. This would probably bring more private players to the field and enhance the development of the microalgae biofuel industry.

The results of the thesis in the following timeframes (1 – 3 years, 3 – 5 years and 5 – 10 years) are presented in Figure 1 and described in detail in chapters 5 – 8.

	Short Term (1-3y)	Medium term (3-5y)	Long term (5-10y)
Environmental drivers		Climate Change 5.1	Potential method for CO ₂ -capturing 5.2
			Potential method for bioremediation 5.3
			Algae can be grown on non-arable land 5.4
			Algae do not need freshwater 5.5
		Tropical Climate 5.6	
Environmental barriers		Land and water are sensible resources 6.1 & 6.2	
Socio-ethical drivers		Man power 7.2	Rural development 7.1
Socio-ethical barriers		Government/Policies 7.3	
		Government/Policies 8.1	
		The lack of data 8.2	

Figure 1. The environmental and socio-ethical drivers & barriers in algal biofuel industry in India.

5 ENVIRONMENTAL DRIVERS

5.1 Climate change

Climate change is a very important driver in the algal energy field. Global warming caused by greenhouse gases (carbon dioxide, methane and nitrous oxide) generated from the fossil fuels is seriously impacting the climate and the nature worldwide. In India the main energy source is coal. About 54% of the electricity is based on coal and this is expected to reach over 70% in the future since the electricity demand is growing rapidly. (Arora 2013.) Another important energy source for India is crude oil. In 2007 India consumed 128.5 Mt of crude oil and, to meet the demand, India has to import about 80% of the oil it consumes. It is estimated that about 70% of the total petroleum consumption is accounted for automobiles and the fuel requirement is increasing with the growing transport demand in the future. India consumes almost five times more diesel than gasoline, so the need for biodiesel is obvious. (Khan et al 2009.)

Indian Ministry of Environment and Forests has published a study about Greenhouse Gas Emissions of India in 2007 to provide information on greenhouse gases emitted from anthropogenic activities on the national level. According to the study the net GHG emissions in 2007 were 1727, 71 MT of CO₂ equivalent, which makes India the fifth largest emitter of greenhouse gases, ranking behind China, the United States, the European Union and Russia. The biggest source of emissions was the energy sector, including electricity, transport, residential and other energy (1100,06 million tons of CO₂ eq) and the second biggest source was the industry sector (412,55 million tons of CO₂ eq) leaving behind the agriculture and waste sectors.

Many sectors of economy in India are climate sensitive, especially since about 51% of the Indian workforce is making their livelihood out of agriculture and related activities (Papola & Sahu 2012). The awareness of the impacts of the climate change increases the need for cleaner renewable energy solutions. Biofuels from indigenous sources have potential to provide energy without any emission of greenhouse gases or other air pollutants. Algae could also provide a

profitable tool to reduce the CO₂ emission levels because of its significant capacity to convert CO₂ into biomass. (Demirbas 2011.)

5.2 Potential for CO₂-capturing

Microalgae cultivation can be harnessed for offsetting the increasing levels of carbon dioxide (CO₂) emissions. Many of the algal species can tolerate and utilize high levels of CO₂, even higher than are found from the atmosphere. Microalgae are able to capture CO₂ from the atmosphere and from soluble carbonates as well as CO₂ from discharge gases from heavy industry. (Chanakya et al 2012.) The most suitable sources for CO₂ capturing are large stationary sources with high concentration of CO₂. In the Indian context this would mean thermal power plants, cement plants, fertilizer plants, refineries and petrochemical plants, and they are in different parts of the country. (Milbrandt & Jarvis 2010.)

In the future it might be possible that countries have to reduce their GHG-emissions and carbon footprint. If that is the case, reducing fossil fuels while simultaneously sequestering CO₂ plays an important role in achieving C-neutrality. Microalgae production for biofuels seems to have great potential in this sense, but there are a few questions with the capturing technology that need to be taken into account, in order to integrate CO₂ capturing system effectively into microalgae cultivation. (Chanakya et al 2012.)

5.3 Potential for bioremediation

Microalgae production for biofuels can be integrated with bioremediation. The nutrients that microalgae need to grow are often waste, such as nitrogen and phosphorous. Microalgae are able to sequester heavy metals by cell walls through adsorption or ion-exchange processes, and the ability can be utilized for bioremediation of heavy metals. (Priyadarshani, Sahu & Rath 2012)

In major Indian cities, 38,354 million liters of wastewater is generated every day, out of which approximately 35% is treated (Gautam 2009). Wastewater contains a lot of nutrients, such as nitrogen (N), phosphorus (P), potassium (K) and other

minor nutrients. The utilization of wastewater in microalgae cultivation helps to produce substantial quantities of algal biomass while microalgae is recovering, recycling and removing nitrogen from wastewaters. Using wastewater for algae cultivation brings down the production costs, since manufactured fertilizers are expensive and they also have a huge C-footprint. (Chanakya et al 2012.)

Different sources, such as industrial wastes, fertilizers, pesticides, geo-chemical structure and mining of metals pollute the aquatic environment with heavy metals (Cu, Zn, Cd, Cr and Ni etc.). They are accumulative, thus once they enter the food chain either from the soil, atmosphere or water they can cause serious threat for human health, since heavy metals can profoundly disrupt biological processes of all organisms. Some heavy metals are essential for nutrition, but they are toxic when present in greater amounts, while others are highly poisonous without any nutritional value. (Priyadarshani, Sahu & Rath 2012.)

Microalgae may offer an economical, effective and safe solution for bioremediation. Biosorption uses biological material that can remove and accumulate heavy metals from aqueous solutions. Microalgae are able to absorb a wide range of toxins and enzymatically degrade the pollutants. This has gained a lot of attention for using microalgae in wastewater treatment, since it may reduce the metal ion concentration significantly. (Priyadarshani et al 2012.)

5.4 Algae can be grown on non-arable land

India has a land area of approximately 297 M ha out of the total country area of 328 M ha. About 179 M ha, which makes about 60% share of the land area is in agricultural use. (FAOSTAT 2011.) In India the arable land is primarily needed for cultivation. Availability for alternative uses of land is low and the land has also other competitive uses. (Chanakya et al 2012)

One of the major environmental drives for algae cultivation is that algae do not need to be cultivated on fertile land, but instead wasteland and other marginal land can be used. The wastelands include degraded crop and pasture land, degraded forest, industrial and mining wastelands and sandy, rocky and bare areas. (Milbrandt & Jarvis 2010.) According to the estimations of Wasteland Atlas of

India by Ministry of Rural Development, India had approximately 44 M ha of wasteland in 2006, which is almost 15% of the total geographical area of the country.

Milbrandt and Jarvis point out in their study *Resource Evaluation and Site Selection for Microalgae Production in India* (2010) that the soils with low permeability (e.g. clay soils) could be challenging for food crop farming, but are suitable for aquaculture as the water loss through seepage or infiltration is low. Saline land is not suitable for agriculture either, but can be used in algae cultivation. There are about 9.8 M ha of salt-affected soils in India out of which 5.5 M ha are saline soils, including coastal land (Pathak, Reddy, Harikrishna, Dhage & Shisodiya 2013). For example the 3 M ha land in the Rann of Kutch area has highly saline soils with groundwater that is more saline than seawater because of the geology of the area. The land in Rann of Kutch would be suitable for algae cultivation also because of the flat terrain and the altitude above sea level. The land is not suitable for food production, although a small part of the area is used in salt manufacture. (Chanakya et al 2012.)

Even though there are algae strains that can be cultivated in brackish or saline groundwater or wastewater, sometimes wastelands are located in areas without decent sources of water. Then one option could be multiple-cropping in crop lands that can support algae cultivation without endangering the crop or algae production. Some of the land under flooded paddy cultivation could be suitable for raising a simultaneous algal crop. Irrigated paddy with constant flooding is currently the most sensible paddy cultivation method for integrated algae cultivation. That would enable to raise algae for about 30 – 60 days giving at least 4 – 8 simple cycles of algae harvest a year. (Chanakya et al 2012)

5.5 Algae do not need fresh water

According to the Ministry of Water Resources, renewable water resources in India are estimated at 1869 km², out of which 1123 km² are estimated to be utilizable. This includes 690 km² of surface water and 433km² of ground water. (Ministry of Water Resources 2013.) Water availability in India is challenged due to growing

water scarcity. Ground water levels and river discharge trends are falling. (Chief Liquidity Series 2009.)

One of the advantages of growing algae over non-edible oil seed crops is that instead of fresh water it can utilize low-quality water, including brackish and saline groundwater and wastewater. It is also possible to grow microalgae in open seas, if used marine and salt tolerant algal species. Algae cultivation does not compete with local agriculture and water needs. (Chanakya et al 2012.)

5.6 Tropical climate

The growth conditions of algae, including climate and weather affect algae production. Sunshine hours and solar radiation have a direct influence on productivity, whereas water supply is affected by precipitation and evaporation, and floods, hails and other extreme weather conditions affect water quality. (Milbrandt & Jarvis 2010.)

In many parts of India, climate is suitable for algae cultivation. Solar radiation of 4.0 kWh/m²/day is adequate to cultivate algae, and annually India receives enough solar radiation apart from the specific areas of Arunachal Pradesh. However, there are monthly variations, and lower solar radiations are experienced in the central, northeastern and western coastal states during the monsoon season and in the northern states during the post-monsoon season or early winter. Sunshine hours have to be more than six per day in order to support algae cultivation. In India sunshine hours vary from less than five (northeastern states) to more than nine hours per day (the western and central states). Again, during the monsoon months the sunshine hours are at their lowest, even under four hours per day, but during other seasons for the most part of the country they can be as high as more than eight hours per day. (Milbrandt & Jarvis 2010.)

Many microalgae species can cope with different temperatures, but most of them are sensitive to freezing. Areas that can experience temperatures below 0°C include the mountain areas in Northern India (states of Jammu and Kashmir, Himachal Pradesh, Uttarakhand, Sikkim, and Arunachal Pradesh). During winters some areas of western Rajasthan may have temperatures less than 0°C. On the

whole, India's climate conditions are suitable for large-scale algae. (Milbrandt & Jarvis 2010.)

6 ENVIRONMENTAL BARRIERS

6.1 Land

Land is a scarce resource in India and land degradation puts the land use questions under the microscope. In a country like India where agriculture plays an important role for people to earn their living the land use is a very important factor for the development of the country. (von Braun, Gulati, Hazell, Rosegrant & Ruel 2005.) There are many issues that affect the land availability for algae production on a large scale, such as physical, economic, legal, social and political factors. For sustainable algae cultivation, agricultural land, environmentally sensitive areas, as well as areas with cultural and historical value have to be excluded. (Milbrandt & Jarvis 2010)

In addition to these problems of the land use, which were also mentioned in the Algal energy roadmap in India by VTT (2014), another problem with land is the price. The land price has been increasing in the past 5 – 7 years and the price increase is likely to continue in the future. Land prices vary a lot depending on location, availability of water and availability of transportation access, and the data on prices is hard to obtain. (Milbrandt & Jarvis 2010.) It might also be difficult for a foreign company to buy land in India and it could only be possible to get it from the rural area where the land ownership is divided to many small farmers. This may lead to challenges with e.g. language and dealing with many landowners, so having a local partner might be necessary.

6.2 Water

In India the water use is often unsustainable. The water scarcity is growing and one major reason is groundwater exploitation. It is estimated that one-third of agriculture relies on irrigation and levels of irrigation efficiency are low. The declining surface water supplies result in growing use of underground reserves and already the greater part of irrigation water is sourced from groundwater. The agricultural sector is depended on groundwater, which makes it vulnerable to the declining supplies. (Chief Liquidity Series 2009.) Therefore, in order to grow

microalgae sustainably, it is not an option to compete with the same water resources with agriculture.

One of the water issues concerning the microalgae cultivation, especially in open ponds is evaporation. According to estimations, at an algal productivity of 10 g dry matter/m²/d and an evaporation rate of 5 – 10 mm from open water surfaces the water lost may be as much as 500 – 1000 l per kg of produced algal dry matter. In many parts of India the water budget is unequal: annual rainfall in mm is much lower than potential annual evaporation mm/year. If fresh water is used for sustainable algae cultivation, this would mean that the cultivation should be practiced for a period when cumulative water loss does not exceed the total annual precipitation and it could vary from 60 d to 270 d. If the area has surplus water that could be used for algae cultivation, raising a food crop needs to be prioritized to maintain food security. Over all, algal cultivation for biofuels is more sustainable when using sea water or when cultivating with paddy under flooded conditions similar to multi-tier cropping. (Chanakya et al 2012.)

7 SOCIO-ETHICAL DRIVERS

7.1 Rural development

One of the drivers that lie behind biofuels, as well as in case of biodiesel from microalgae, is their potential to contribute to rural development. In the past, the Indian economy could be described as agrarian economy with an enormous share of the total work force in agricultural employment, but that is not the case today. Even though India is one of the fastest growing economies in the world with a thriving service sector, the agricultural sector is facing serious problems and has almost stagnated. (Nanda 2010.) In 1972 – 1973 the share of agriculture from total employment was 74%, and the share declined to 51% in 2009 – 2011. The shift is even more important when considering what share agriculture has in the gross domestic product (GDP). In 1972 – 1973 the share of agriculture was 41%, but in 2009 – 2010 it was only 15%. (Papola & Sahu 2012.) This make a difference for the country, since nearly three-quarters of families depend on rural incomes and also the majority of poor people live in the rural areas (India: Issues and Priorities for Agriculture 2012).

The Government of India is taking steps towards diminishing rural poverty through several actions. One of the focus areas is creating employment in rural areas (Planning Commission Government of India 2013.) Biofuel business could bring more public and private investments to rural areas and generate additional employment and income for farmers and landless people (Altenburg, Dietz, Hahl, Nikolidakis, Rosendahl & Seelige 2008). The ability of algae to be grown on degraded land increases the productive use of underutilized land.

Microalgae production for biodiesel could provide new employment opportunities. Depending on chosen production utility for microalgae (closed photo bioreactor or open pond), the skills required from the labour force vary. (Adenle, Haslam & Lee 2013.) If the processing facilities of microalgae are sited near the growing facilities in the rural area, local economies could be stimulated. This may also lead to a need for better infrastructure of the area, such as roads, which would create jobs for local people.

7.2 Man power

India has a population of 1.22 billion people out of which more than 50 % is below the age of 25. With population growth rate of 1.58% the population is expected to reach more than 1.53 billion people by the end of the year 2030. Most of the population, about 72 %, lives in villages and the rest in urban areas. (Population of India 2013. 2013.)

Ministry of Statistics & Programme Implementation has published on the website of Press Information Bureau the Key Indicators of Employment and Unemployment in India (2013). According to the website about 40 % of the population belonged to the labor force in 2011 - 2012 (41 % in rural areas and 37% in urban areas). For men the labor force participation rate was almost 56 % and for women 23 %. About 49 % of the workers were engaged in agricultural sector, 24 % in the manufacturing and construction sector (secondary sector) and 27 % in the service sector (tertiary sector). Unemployment rate was nearly 2 % at the all-India level, which means that there are about 28 million unemployed people in India. The unemployment ratio was a little higher in urban areas (about 3 %) than in rural areas (about 2 %).

7.3 Policies/Government

India acknowledges the opportunities that lie within the renewable energy sources. Since they are indigenous, non-polluting and virtually inexhaustible, biofuels could provide a sustainable solution to the increasing energy demand enhanced by growing economy, which is one of the fastest growing economies in the world. To keep up with the socio-economic development, India has to meet the growing energy demand and ensure the energy security of the country. (National Policy on Biofuels 2013.)

The Government of India has promoted the utilization of biofuels by making it mandatory to blend bioethanol with gasoline and biodiesel derived from non-edible oils with diesel (5% blending) since October 2008 (National Policy on Biofuels 2009). In December 2009 the Government of India released National Policy on Biofuels formulated by the Ministry of New and Renewable Energy.

The vision of the policy is to accelerate development and promotion of the cultivation, production and use of biofuels to increasingly substitute petrol and diesel consumption. The goal is to ensure that a minimum level of biofuels become readily available in the market to meet the demand at any given time. The new blending target of the policy is to reach 20% blending with biofuels by 2017.

The policy emphasizes the importance of using inedible sources for biofuels that could be grown on degraded soils or wastelands that are not suited for agriculture, to avoid the competition between food and energy crops. The policy supports innovation, research and development on biofuel feedstock production including second generation biofuels. It also holds other incentives through which the biofuel sector is made more attractive, such as setting a Minimum Support Price for inedible oil seeds to provide a fair price for growers. The Government of India also proposes to consider creating a National Biofuel Fund providing financial incentives, such as subsidies and grants for new and second generation feed stocks, advanced technologies and conversion processes if necessary. Biodiesel and bioethanol are proposed to be left outside of central taxes and duties with an exception of 16% excise duty with bioethanol. (National Policy on Biofuels 2009.)

The Government of India sees the indigenous biofuels and especially biodiesel in the transportation sector as the key for the energy issues the country is facing. The National Policy on Biofuels and the National Biodiesel Mission (launched in 2003) are encouraging actions towards biofuels.

8 SOCIO-ETHICAL BARRIERS

8.1 Government/Policies

Although the Government of India has formulated policies that regulate the biofuel field and favor the usage of biofuels they seem to be inadequate when concerning future biofuels, such as algae energy. The National Biofuel Policy relies on molasses as a source for bioethanol and The National Mission on Biodiesel focuses on jatropha as a source for biodiesel to achieve its stated goals. Despite the efforts of the government and private sector, the biofuel industry is still in infancy and jatropha as a biodiesel source is facing serious problems. The original target of the government was to produce sufficient biodiesel to meet the mandate of 20% diesel blending by 2012. It could not have been achieved because of the lack of sufficient jatropha seeds as well as lack of high-yielding drought-tolerant cultivars. (Aradhey 2013.) Problems were also caused by smaller land holdings, ownership issues with government or community-owned wastelands, inefficiency of state governments and insufficient production of biodiesel (Zafar 2013).

The government along with the National Biofuel Policy and The National Mission on Biodiesel has been criticized due to unsuccessful results on the production and commercialization fronts to meet the country's energy demand (Aradhay 2013). Although the policy promotes research and development of suitable technologies for production of advanced biofuels, including microalgae, and as it also came up with the interviews (2013), the microalgae energy field is now in a situation where it is waiting for the government's next step. There are no strict laws and policies for the microalgae energy field and how the government will react towards the field will be significant for its development. When the policies for microalgae energy are formulated, it is important to learn from the mistakes that occurred with The National Biodiesel Mission and jatropha, in order to develop a sustainable renewable energy source that can meet the demand for alternative energy.

8.2 The lack of data

Although microalgae could provide a strong solution for India's energy demand, there are still possesses questions that need to be answered in order to avoid the same problems that happened with jatropha cultivation for biofuel purposes.

The study Sustainability of Large-Scale Algal Biofuel Production in India published by Indian Institute of Science (2012) has summarized key areas that need to be focused on in the future. In order to have algal strains with high oil yield and strains that are well suited to Indian conditions it is necessary to develop and improve algal strains and the species need to be tested in the field in different conditions. Algal cultivation technologies need more development and they need to be simplified and decentralized in order to bring the technologies out into villages. In order to develop microalgae energy towards large scale production in a sustainable way, effective policies are needed, so that the food security of India is not threatened.

9 DISCUSSION AND CONCLUSIONS

The aim of the thesis was to characterize the factors that influence the sustainability of algal energy in India. Algae as an energy source seem to have a lot of potential when sustainable development is considered. Cultivating algae over oil-seed crops offers a more sustainable method for biofuel production, since algae can be grown without fresh water and it can be cultivated on wastelands that are not suitable for agriculture. However, land and water are very sensitive resources in India, so when the cultivation location is determined, there has to be a certain amount of caution involved. Algae also have a huge potential for bioremediation and wastewater treatment, and these can be integrated into algae cultivation. Algae are also able to sequester CO₂ and these abilities have raised a lot of interest in the algae energy field. While algae are grown for renewable energy purposes they can also be utilized in degrading pollutants from both water and air. This is seen as a major driver in the field, since it is very likely that countries have to restrict their carbon levels in the future.

The biofuel field may offer a well-needed boost for the agricultural sector in India. Most of the population lives in the rural area and even though the economy of the country is growing, the agricultural sector is struggling. Algae cultivation and refining facilities may enhance the rural development, if desired. As within every industry, in the algal energy field transparency is needed in order to act ethically among rural people.

According to the interview study, India is very keen on building a strong and valid biofuel industry. Algae have a lot of potential, but they may not be only favorable option. For the algae energy industry to grow sustainably, strict policies and laws are needed. Currently the algal energy field in India is waiting –what will be the government's next step towards indigenous biofuels?

On the whole, the interview research gave us a lot of perspective and data about the algal biofuel situation in India. Mainly the interviewees were willing to share their knowledge and they were also keen to present their achievements in the field. As anticipated beforehand, the interviews became conversations rather than plain questions and answers. All of the gathered results from the different

interviews supported each other –there were no significant differences among the interviewees about the algal biofuel field and its future scenario, which confirmed the validity of the gathered data.

The results of the interview study were quite similar when compared to the information gained from the literature study. The drivers and barriers were the same, but from the interviews it was easier to sense the importance of this particular issue for the future development of the field. Many of the interviewees named the same drivers or concerns among the field and many of them stated that currently the technology is too expensive to compete with the price of petroleum oil on a large scale, but the ability of algae to sequester CO₂ and the fact that algae can be cultivated in wastewater are so important drivers that the future for algae energy seems bright even though the technology still needs developing.

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